Space Aerogel

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On April 3, 1996, the first space samples of aerogels were produced by NASA in low-Earth orbit on the Starfire Rocket. Aerogel is the lightest solid known—only three times the density of air. A gel is an amorphous solid formed from a liquid with defined gellation conditions for temperature and concentration. As the only known transparent insulator, aerogel is a supercritically dried gel with all its liquid removed—sometimes garnering the name "frozen smoke." A block the size of a human weighs less than a pound. An inch thickness can shield a hand from the heat of a blowtorch. A sugar-cube-sized portion of the material has the internal surface area of a basketball court.

The formation of these gels has attracted space research, owing to the strong influence of gravity on how a gel is formed. "Practically all biochemical processes which occur in living beings are proceeding in medium with a sol-gel balance of all components. If fragments of gel phase depend on gravity, it can be an additional way for gravity to influence living beings, including humans."[1] In fact, "gel formation can display very high gravitational dependence… The structure of gel matrices obtained on Earth and in orbital conditions has been found to be different… space processing of gels could be quite advantageous… microgravity conditions can allow gels with a more uniform or prescribed structure."[2]

Aerogel is transparent because its microstructure is very small compared to the wavelength of light. However, as currently processed on Earth, all but the clearest aerogels scatter some light at the blue end of the spectrum giving them a slightly hazy appearance. The scattering can be thought of as arising from the large holes or pores that have a lower index of refraction than the average of the aerogel, i. e., index of refraction 1.00 versus 1.02. Thus research on aerogel preparation to improve its clarity currently is focused on minimizing the number and size of the large pore population in the aerogel.

When characterized for porosity (nitrogen adsorption and desorption), the space aerogel showed a four-fold reduction in pore sizes in the 17- to 3,000-Å range, compared to otherwise identical ground controls. Since the light scattering varies with pore size to the sixth power, a calculated reduction in opacity of 4,000 times is derived. The difference in porosity may arise from lack of sedimentation during the early stages of space gellation, in which large gel particles entrap or occlude solvent into a mosaic rather than a more close-packed structure. The comparison between ground and space samples becomes more striking when pore volume is considered, since more than a decade and a half of ground research typically produces pore volumes in the range of 5 to 7 cm^3/g (inverse density), but the space aerogel has a benchmark value of 1.07 to 1.6 cm^3/g. For pure solid silica (0.5 cm^3/g) with no pores, the space aerogel is remarkably close to the values expected from a 30 to 50 percent solid, compared to the typical 5 to 10 percent solid material encountered on the ground. The next generation aerogel experiment will be optimized for longer, more quiescent conditions in the Shuttle middeck.

According to the "Technology to Watch" section of *Fortune Magazine* (1992), the overall market for the aerogel industry worldwide is projected to include more than 800 potential product lines ranging from surfboards to space satellite components.

Research Milestones:
- June 1995, KC–135 Low-Gravity Production of Low-Density Silica Flocs (results published in *Microgravity Science and Technology*, 1995).
- April 1996, microgravity Starfire rocket flight successfully forms 32 samples of aerogel.
- June 1996, publication of "Ground-Based Studies on Aerogel Transparency." *Journal of Materials Research*, 1996.
- September 1996, received first porosity data from rocket flight; results being analyzed, but indicate 4 to 5 times improved pore size control in the space-processed aerogel.

[1]Leontjev, V., et al.: Micro-g Science Symposium, Moscow, May 13–17, p. 274, 1991.
[2]Bogatyreva, et al.: Sixth ESA Conference ESA-SP-333, vol. 1, 1992.

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Biographical Sketches: Dr. David Noever is a research scientist in the Space Sciences Laboratory at Marshall. He has held this position since 1991. His association with Marshall began in 1988 as an USRA visiting scientist. Noever currently initiates and designs microgravity experiments in materials processing, with particular emphasis on aerogel production. Noever received his B.S. degree in chemical engineering from Princeton University, Princeton, N.J. in 1984. He graduated summa cum laude; was a Phi Beta Kappa; and a Chevron Scholar. He earned his Ph.D. in theoretical physics at Oxford University, Oxford, U.K., in 1988. While there he was a Rhodes Scholar and earned a Silver Medal at the Royal Society of Arts, London, U.K.